THE PRESENT HABITABILITY POTENTIAL OF GALE CRATER: WHAT WE HAVE LEARNED SO FAR FROM MARS SCIENCE LABORATORY. P. G. Conrad[1], P. D. Archer[2], S. Domagal-Goldman[1], J. Eigenbrode[1], M. Fisk[3], S. Gupta[4], V. Hamilton[5], L. Kah[6], Henrik Kahanpää[7], J. Martin-Torres[8], J. Martinez-Frias[8], C.P. McKay[9], D. Ming[10], M.E. Minitti[11], R. Navarro-Gonzalez[12], T. Owen[13], A. Pavlov[1], A. Steele[14], J. Stern[1], A. Trieman[15], M-P Zorzano[5] and P.R. Mahaffy[1]

[1]NASA Goddard Space Flight Center, Code 699, Greenbelt, MD 20771 Pamela.G.Conrad@nasa.gov, [2]Jacobs, NASA Johnson Space Center, Houston, TX 77058, [3]Oregon State University, Corvallis, OR 97331 USA, [4]Imperial College London, London, UK, [5]Southwest Research Institute, Boulder, CO, USA, [6]University of Tennessee, Knoxville, TN, [7]Finnish Meteorological Institute, P.O. BOX 503, FI-00101, Helsinki, Finland, [8]Centro de Astrobiologia (INTA-CSIC), Madrid, Spain, [9] NASA Ames Research Center, Moffett Field, CA 94035, USA, [10]NASA Johnson Space Center, Houston, TX 77058, USA, [11]Planetary Science Institute,1700 E. Ft. Lowell, Suite 106, Tucson, AZ 85719, [12]Universidad Nacional Autónoma de México, México, D.F. 04510, Mexico, [13]The University of Hawaii, HI, [14]Carnegie Institution of Washington, Washington D.C. 20015, USA, [15]Lunar and Planetary Institute, 3600 Bay Area Blvd., Houston TX 77058

Introduction: The Mars Science Laboratory mission has comprehensively interrogated the surface environment of Mars as it explores Gale Crater. Both chemical and physical attributes of the present environment have been measured over the course of the mission, enabling us to compare the present state of the martian surface with the environmental requirements of prokaryotic microbes. While this approach does not exclude the possibility of martian life that may have evolved to adapt to the present conditions, it is advantageous in that it allows us to evaluate environmental requirements of known life and also provide insight into the likelihood of forward contamination by Earth organisms with the comparison of their environmental requirements with the measured attributes of the environment at Gale Crater.

We have already modeled a paleoenvironment with high habitability potential (HP) based upon chemistry, mineralogy and other geological evidence such as sedimentary structures and larger scale geomorphology [1]. In this report, we turn our attention to the present HP of the Yellowknife Bay area, including the importance of the physical environmental metrics such as atmospheric pressure, air and ground temperature, ionizing radiation, wind speed and direction, slope, etc.

Measurements: At the atmosphere-surface interface, Gale Crater has presented us with basaltic minerals and their alteration products [2, 3]. Geomorphologies as well as direct wind measurements provide a glimpse of a mechanically dynamic environment, and chemical analyses do not suggest much chemical weathering of the rocks that we have studied so far with the Curiosity payload. Three samples: Rocknest wind drift, and the John Klein and Cumberland mudstones of the Sheepbed Unit from Yellowknife Bay, have been characterized with the CheMin powder X-ray diffractometer, and the two rock samples show the presence of phyllosilcate minerals, evidence for aqueous deposition. The rocks that we have studied can be evaluated as potential habitat on the basis of their chemical and physical attributes.

Chemistry. Major elemental requirements for Earth prokaryotic life are present in the John Klein and Cumberland rocks (C, H, O, N, P, S) and many trace elements used by life as-we-know-it are also observed, e.g., Mg, Fe, Si, Cl, Li and Br [1].

The geochemistry of the rock samples is consistent with that of Earth rocks that can readily host microbial communities in the pore spaces or in fracture voids, so the rocks do not pose any potential chemical environmental threat [4].

Gases that have been thermally evolved by the Sample Analysis at Mars (SAM) suite when sampling the Yellowknife Bay samples show an inventory of volatile compounds that are both metabolically useful and indicative of more moderate redox conditions than the present surface. These include: H_2O, CO_2, SO_2, O_2, H_2, H_2S, HCl and NO in order of abundance [5].

The Dynamic Albedo of Neutrons (DAN) instrument has also observed water as the rover traversed the units in Yellowknife Bay, indicating water equivalent hydrogen abundance of 2-3 weight % in the top 60 cm in the Sheepbed unit [6]. The present martian surface does not have standing liquid water, and the diurnal and variations in atmospheric humidity as have been recorded throughout the mission by the REMS investigation [7] are small, perhaps due entirely to temperature variation, so it is not clear how much exchange exists between atmosphere and surface.

Physics. Environmental characteristics such as temperature, porosity and permeability, ionizing radiation, wavelength and flux of available sunlight, and mechanical stability all play a role in habitability. The thermal environment is one primary constraint on HP

because it not only determines the stability of required chemical species such as water, but it also determines how much energy will be required for metabolic chemistry. With respect to rock as potential habitat, dark rocks can be tens of degrees Celsius warmer than light rocks, and depending upon other physical properties, may have much higher thermal inertia, moderating the temperature of a potential cryptoendolithic or chasmolithic environment. Both the heat capacity of the minerals and the aggregate thermal properties of rock can contribute to making a more stable thermal environment conducive to the chemistry of metabolism than can the surface/atmosphere interface. The Sheepbed rocks are not especially dark (Fig 1), nor are they very porous, making them poor candidates for a habitat.

Fig 1: John Klein (left) and Cumberland (right)

The max and min ground temperatures have been monitored daily by the REMS instrument [8], and these measurements indicate that the surface of the Sheepbed Unit would be a challenge for viable organisms. The diurnal swing is substantial ~75 to ~95 °C between max and min (Fig 2) and viable organisms of known extremophiles can only withstand a minimum of about -18 °C [9].

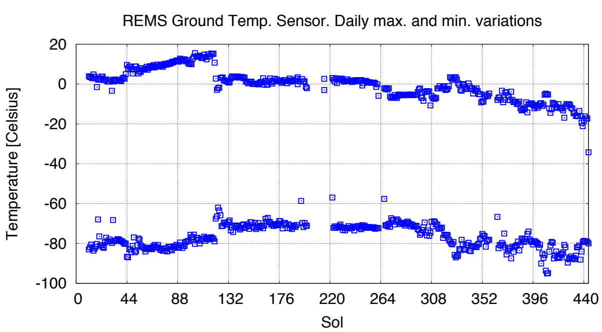

Fig 2: REMS ground sensor measurements

The flux of ionizing radiation at the martian surface has been measured continuously by the Radiation Assessment Detector (RAD) investigation, including not only background galactic cosmic rays, but also solar energetic particles [9]. The absorbed dose that RAD measured at the surface at Gale Crater averages 76 mGy/yr, which would be a challenge over time, even for radiation adapted organisms such as *Deinococcus radiodurans*, which can endure 20 kGy of gamma radiation and then repair itself. But in a rock interior of sufficient density and depth, radiation adapted organisms could persist in alternately dormant and viable phases. Viable terrestrial microbes carried on a spacecraft are not likely to survive the radiation environment for very long in such an environment.

Discussion: The combined challenges of diurnal swings into temperatures that are too low for the most cold adapted microbes we know of, radiation doses that would not be survivable over the long term in a viable state and lack of pore space in the Sheepbed rocks lower their habitability potential. The more neutral redox environment within Cumberland and John Klein is more favorable for life than the extremely oxidizing condition on the surface of the rocks and dust cover.

We note that there is a distinction between the rock characteristics with the highest preservation potential for habitable paleoenvironments and the rocks that are the most optimal candidates for *presently* habitable environments. So what is good for preservation of past habitable environments presents a problem for present habitation.

While the Sheepbed Unit rocks of Yellowknife Bay indicate a martian *past* with promising habitability potential, they are poor candidates for harboring organisms now, not because of their chemistry, but because of their physical characteristics.

References: Use the brief numbered style common in many abstracts, e.g., [1], [2], etc. References should then appear in numerical order in the reference list, and should use the following abbreviated style:

[1] Grotzinger J. P. et al. (2013) *Science* **343**.6169 [2] Blake, D. F., et al. (2013) *Science* **341**.6153: 1239505. [3] Vaniman, D. T., et al. (2014) *Science* **343**.6169: 1243480. [4] McLennan, S. M., et al. (2014) *Science* **343**.6169: 1244734. [5] Ming, D. W., et al. (2013) *Science* **343**: 6169. [6] Litvak, M. L. et al. (2013) AGU Fall Meeting 2013, abstract #P14B-07 [7] Genzer, M. et al. *EGU General Assembly Conference Abstracts*. Vol. 15. 2013. [8] Hamilton, V. E., et al. (2014) *J of Geophys Res: Planets*. [9] Rothschild, L. J., and R. L. Mancinelli. (2001) *Nature* 409.6823: 1092-1101. [10] Hassler, D. M., et al. (2014) *Science* 343.6169: 1244797.

Acknowledgements: The MSL mission is supported by the NASA Mars Exploration Program, Science Mission Directorate, and it is managed by the Jet Propulsion Laboratory, California Institute of Technology.